Michigan Tech Smart Grid

Education and Laboratories

Bruce A. Mork

Professor, Director Power & Energy Research Center
Department of Electrical and Computer Engineering

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Bruce A. Mork, PhD, PE

Professor, Electrical Power Systems
Director, Power & Energy Research Center

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Education:

- BS Mechanical Engineering, NDSU, 1979
- MS Electrical Engineering, NDSU, 1981
- Doctoral Researcher, NTNU, 1990-91
- PhD, Electrical Engineering, NDSU, 1992

Experience:

1992-date: **Michigan Technological University**

2013-14: Sabbatical at **NTNU**, research development.

2001-02: **SINTEF Energy Research/NTNU**, Trondheim, Norway

- Fulbright Senior Scientist; Research Council of Norway Visiting Researcher

1990-91: **NTNU**, PhD Exchange Student, Visiting Researcher

1989-90: **Statnett**, Husebybakken, Oslo, Norway

- Research Engineer: Relay Protection Group, Forensics, EMTP Studies

1982-86: **Burns & McDonnell Engineering**, Kansas City, MO

- Substation Design Engineer: 12.47-kV to 345-kV
  Station layout, high-voltage equipment, grounding, rigid bus, raceways, protection, relay control panels, SCADA, communications

1979-80: **HDR** (formerly SSR), Bismarck, ND

- 69-kV and 115-kV Trans Lines: Surveying, design, construction management

Norway Experience

- 1989-91 – **Statnett**, Husebybakken. Research Engineer.
  - Relay Protection Group: Per-Odd Gjerde, Steinar Gjevre
  - EMTP simulations to identify relay misoperation
  - Main project – Sima transformer-cable differential protection
- 1991-92 – **NTH**. Forskningsrådet stipendiat. PhD student/researcher.
  - Host professor: Morten Anker. EMTP modeling, ferroresonance.
- 2001-02: **SINTEF Energy Research/NTNU.** Sabbatical year.
  - Fulbright Senior Scientist; Forskningsrådet Visiting Researcher
  - Hosts: Thor Henriksen, Hans Kr. Høidalen
  - EMTP transformer modeling for ferroresonance & switching
- 2007, 2008, 2011, 2015: **NTNU**, 6-8 week stays each summer.
- 2013-14: **NTNU.** Visiting professor/researcher. Sabbatical year.
  - Research development for relay protection & smart grid
  - SIU (Senter for Internasjonalisering og Utdanning) Smart Grid Project

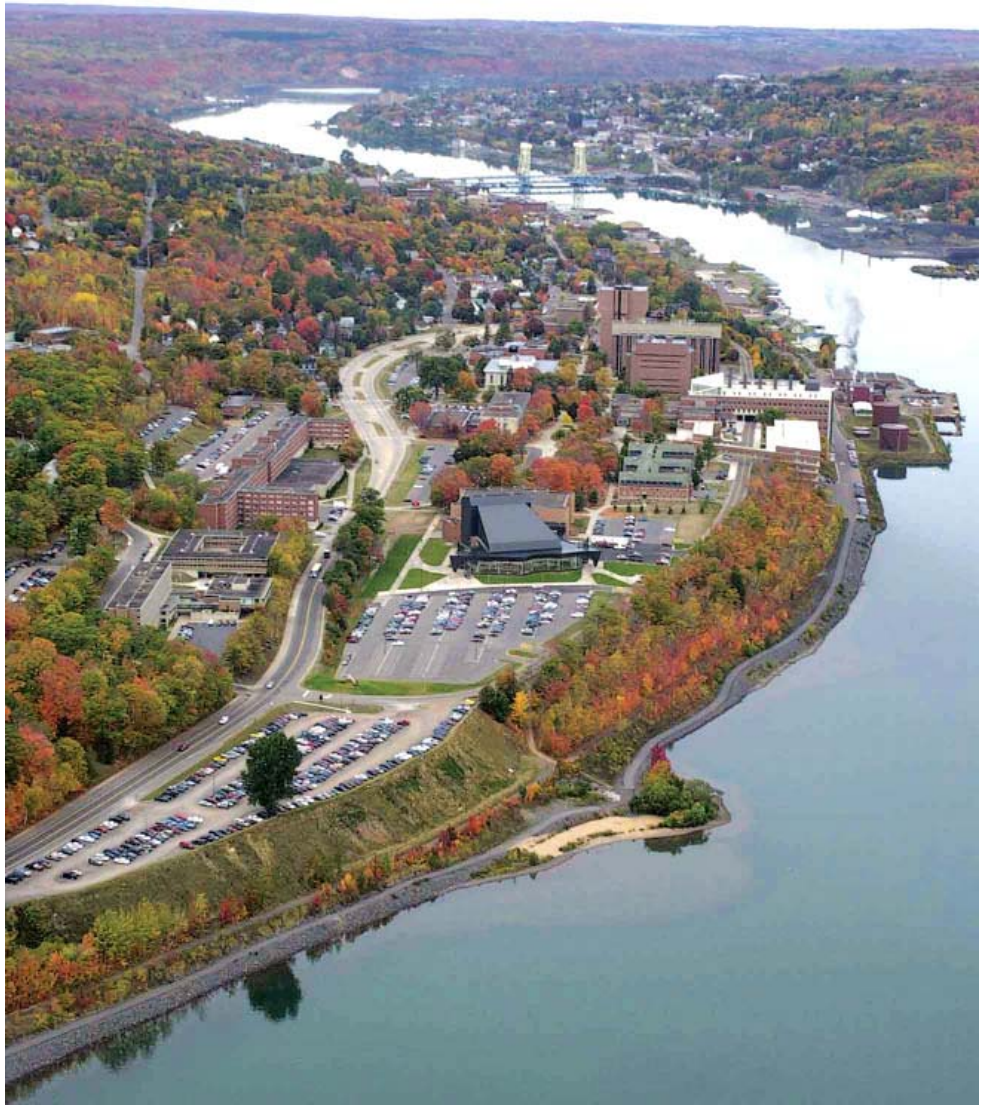
NTNU-MTU cooperation

- Electromagnetic transients program
  - ATPDraw development – BPA connection
  - Hybrid transformer development and implementation
- KMB - Transformer performance 2006-2010
  - Nicola Chiesa (NTNU) - Transformer inrush currents
  - Alejandro Avendaño (MTU) – Internal faults
- FP – Offshore HV Windfarm technologies
  - Edris Zagreb (NTNU) – HF transformer design
  - Himanshu Bahirat (MTU) – HV DC collection systems
- KPN – ProSmart
  - Zagros Shahooei (MTU) – Voltage Stab, Wide Area Control
  - Konstantin (NTNU) – protection in distribution systems
  - Jaya Yellajosula (MTU) - wide area protection

Location

Michigan Tech - Houghton, Michigan. In the Upper Peninsula.

Michigan Tech



- Enrollment – approx 7,000 Students.
- About 10% are international, about 10% are graduate students.
- About 3,800 enrolled in engineering, math, sciences.
- Electrical Engineering has over 600 BS students, about 50 PhD students, and 130 masters students.
- Online MSEE program in Power Systems.

Spring & Summer

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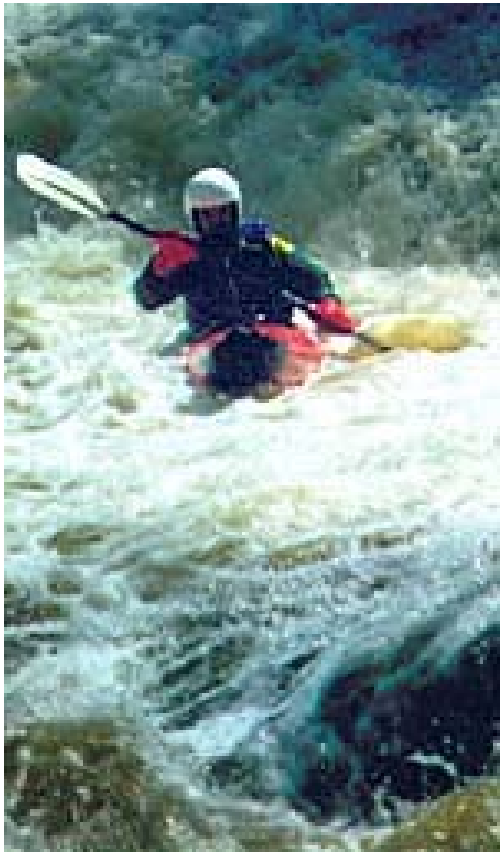
There are many clean sand beaches, making for refreshing getaways on the weekends. Other activities are sailing, swimming, water skiing, fishing, mountain biking, golfing (Michigan Tech operates a golf course), kayaking, etc.



Central ECE/PERC Power Faculty

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- **Dr. Bruce Mork, Center Director**
  - – Power System Transients, EMTP
  - – Power System Protection, Smart Grid, WAMPAC, wind power
  - – Nonlinearities, Chaos Theory
  - -- BPL - Broadband over Powerline

- **Dr. Leonard Bohmann, Assist. Director**
  - – FACTS (Flexible AC Transmission Systems)
  - – Motor Drives
  - – Power Quality
  - – Power System Transients, Operation

- **Dr. Lucia Gauchia**
  - Energy Storage Systems
  - State estimation for batteries and supercapacitors

- **John Lukowski**
  - – Electronics, Energy Conversion, Renewable Energy
  - – Automotive Electronics, Hybrid and Electric Vehicles
  - – Smart Meters, Home Energy Management

- **Dr. Wayne Weaver**
  - – Power Electronics -
  - – Micro-Grids
  - – Alternate Energy – Wind and Solar
  - – Motor Drives

- **Dr. Dennis Wiitanen**
  - – High Voltage Engineering, Dielectrics
  - – Reliability Analysis
  - – Electric Machines (Motors, Generators, Transformers)

- **Dr. Chee-Wooi Ten**
  - – Smart Grid Technologies
  - – Cybersecurity
  - -- Emergency Control
  - -- Self-Healing systems
  - -- DMS

- **Dr. Sumit Pudyal**
  - Power System Operations
  - Real-time digital and analog control.
  - Power System Protection

Online Energy Education

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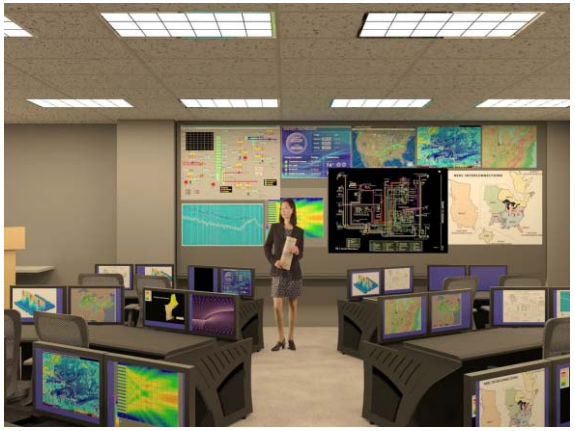
Courses	Certificate	Adv Cert	MSEE
EE 3010 – Circuit Analysis	✓		
EE 3120 – Energy Conversion, Renewables	✓		
EE 4219 – Intro to Motor Drives	✓		✓
EE 4221 – Power Systems I	✓	✓	✓
EE 4222 – Power Systems II	✓		✓
EE 4227 – Power Electronics	✓	✓	✓
EE 5200 – Advanced Analysis of Pwr Syst		✓	✓
EE 5220 – Transient Simulation (EMTP)		✓	✓
EE 5221 – Advanced Machines & Drives		✓	✓
EE 4223/5223 – Power System Protection	✓	✓	✓
EE 5230 – System Operation		✓	✓
EE 5240 – Computer Methods		✓	✓
EE 4225/5250 – Distribution Systems	✓	✓	✓
EE 5260 – Wind Power & Grid Integration		✓	✓
EE 5295 – Advanced Propulsion Systems for HEDV		✓	✓
EE 5750 – Distributed Embedded Control Systems		✓	✓
EE 6210 – Power System Stability		✓	✓

On Campus Laboratory Facilities

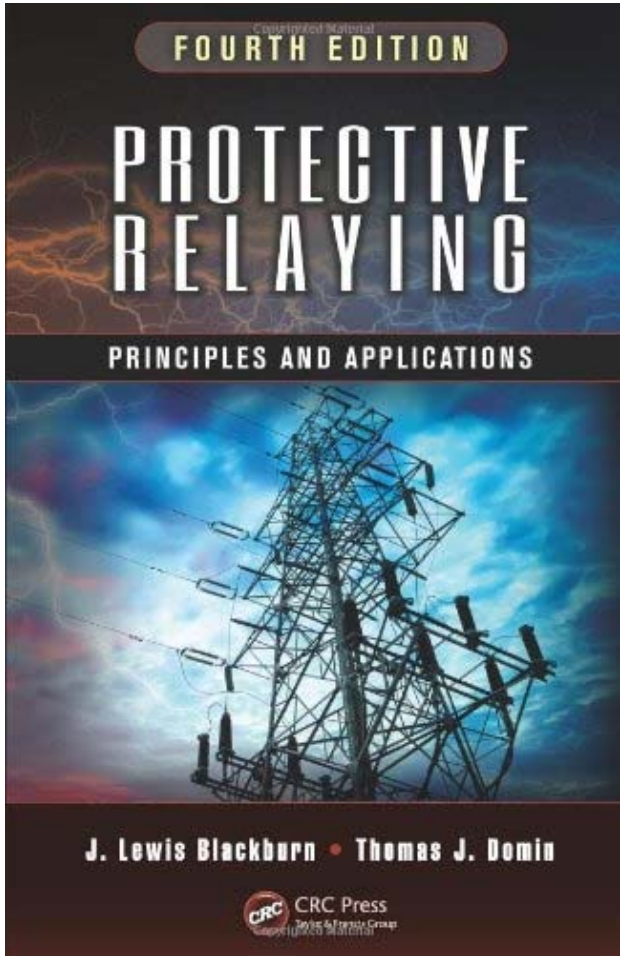
- Relay Protection Lab
- Power Systems Lab
  - Transformers, Ferroresonance, Relay testing
  - EMTP, Power Quality, Power Line Communications



- Smart Grid Operations Center
  - Energy Management: EMS, DMS, SCADA
  - Synchrophasors, Wide Area Control & Protection
  - Cybersecurity
- Power Electronics Research Lab
  - Power Converters, Power Quality
  - Microgrid Lab
  - Control System Design, Prototype and Testing

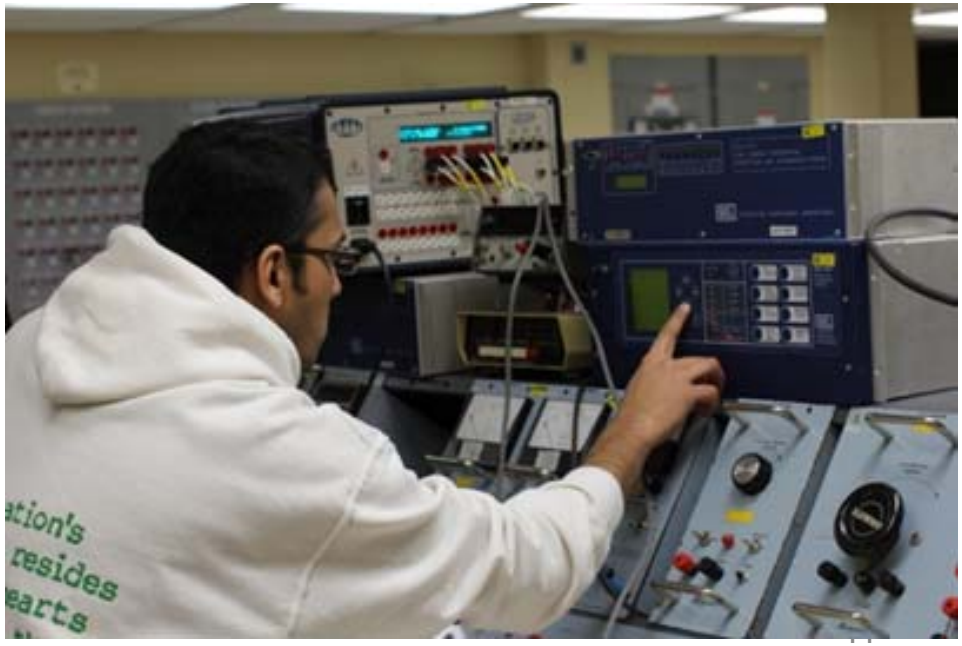
EE 5223 Course

- http://www.ece.mtu.edu/faculty/bamork/EE5223/
- Software for short circuit, coordination, waveforms:
  - ASPEN, Doble, ATP, Cyme. Also have PSS/E, CAPE.
- Software usage integrated throughout
- Complete “protection chain”
  - CTs, VTs, relays, control, comm, CBs.
- Understanding of system, interactions
- Protection philosophies
- Knowledge of equipment protected
- Relay inputs, polarization, outputs
- Relay functionalities, applications



Relay Protection Lab

G1: Electromechanical – G2: Electronic -- G3: Microprocessor



EE 5224 - Lab Exercises

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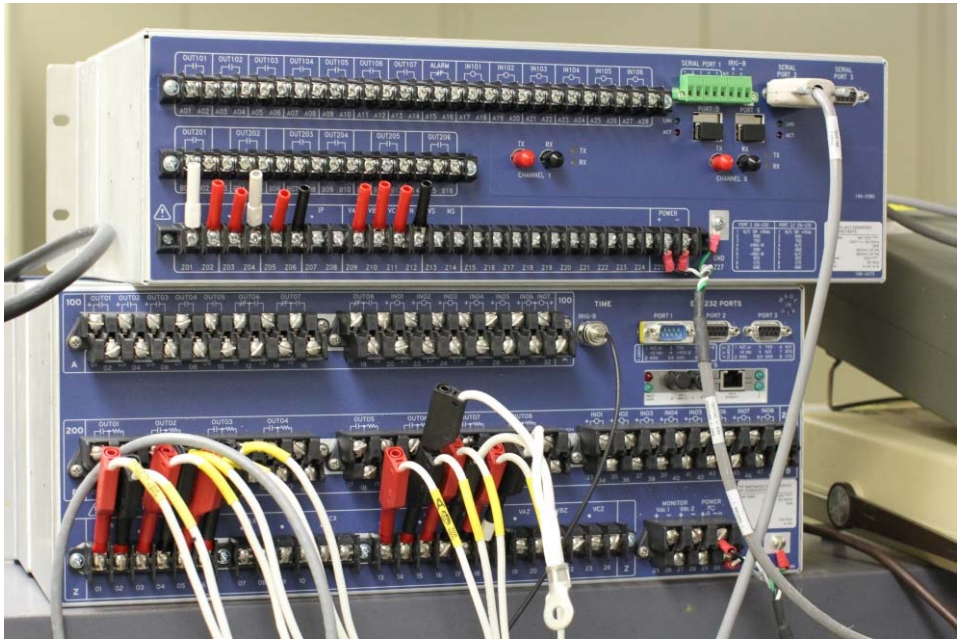
- Introduction, safety, relay tester, software, basic relay settings, testing, time overcurrent.
- SEL (Interoperability: GE, ABB, Siemens & Beckwith)
- Radial coordination
- Directional overcurrent
- Differential protection – bus and transformers
- Distance protection, coordination
- Communications, permissive or blocking.
- Introduction to PMUs, synchrophasors.
- Next: advanced lab on DSP, 61850, WAMPAC.

Synchrophasors

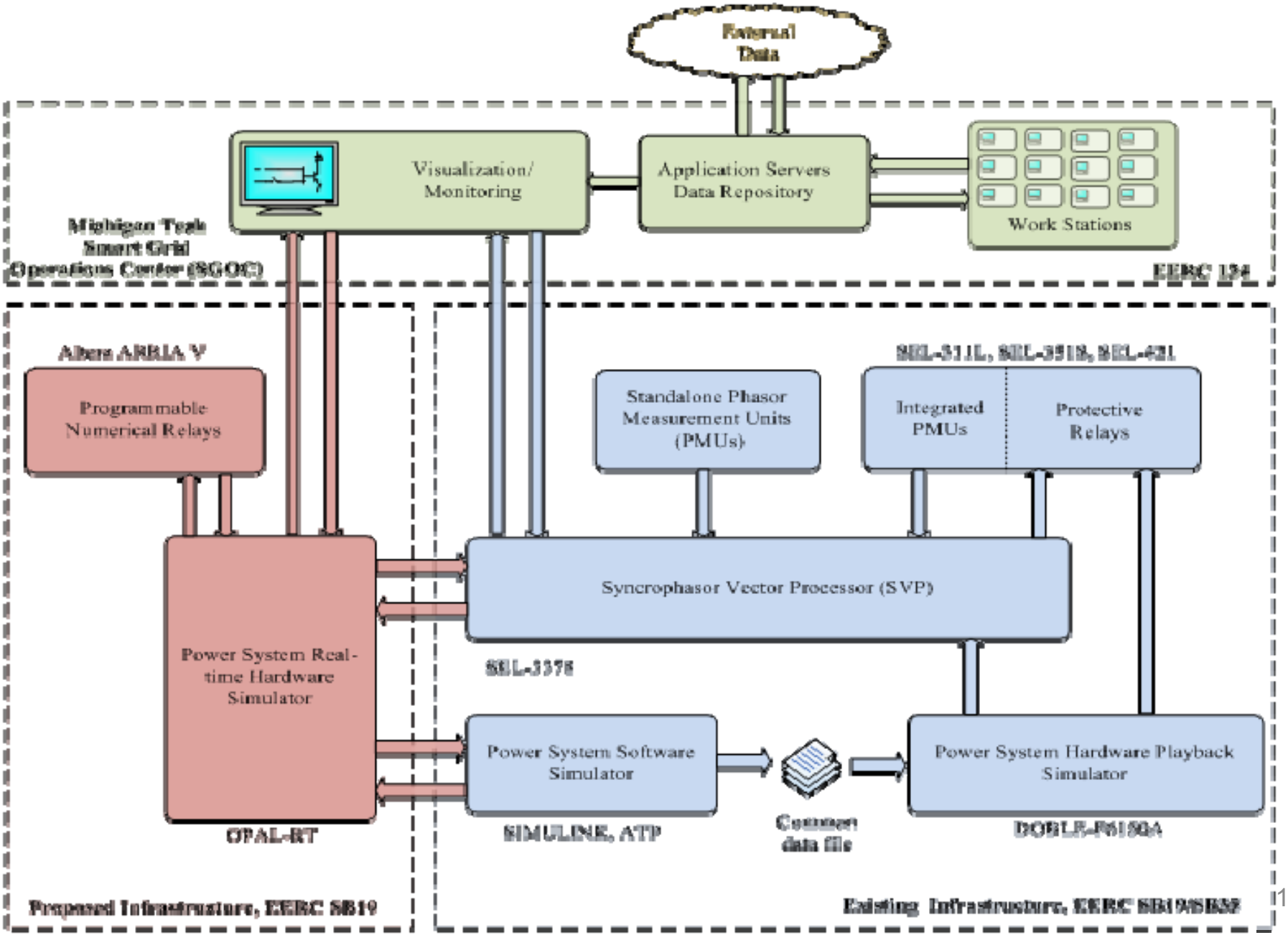
GPS
Antenna

Synchrophasor Data Concentrator



Relays with GPS input and
Phasor Measurement Unit (PMU)

Smart Grid Operations Center



Smart Grid Operations Center

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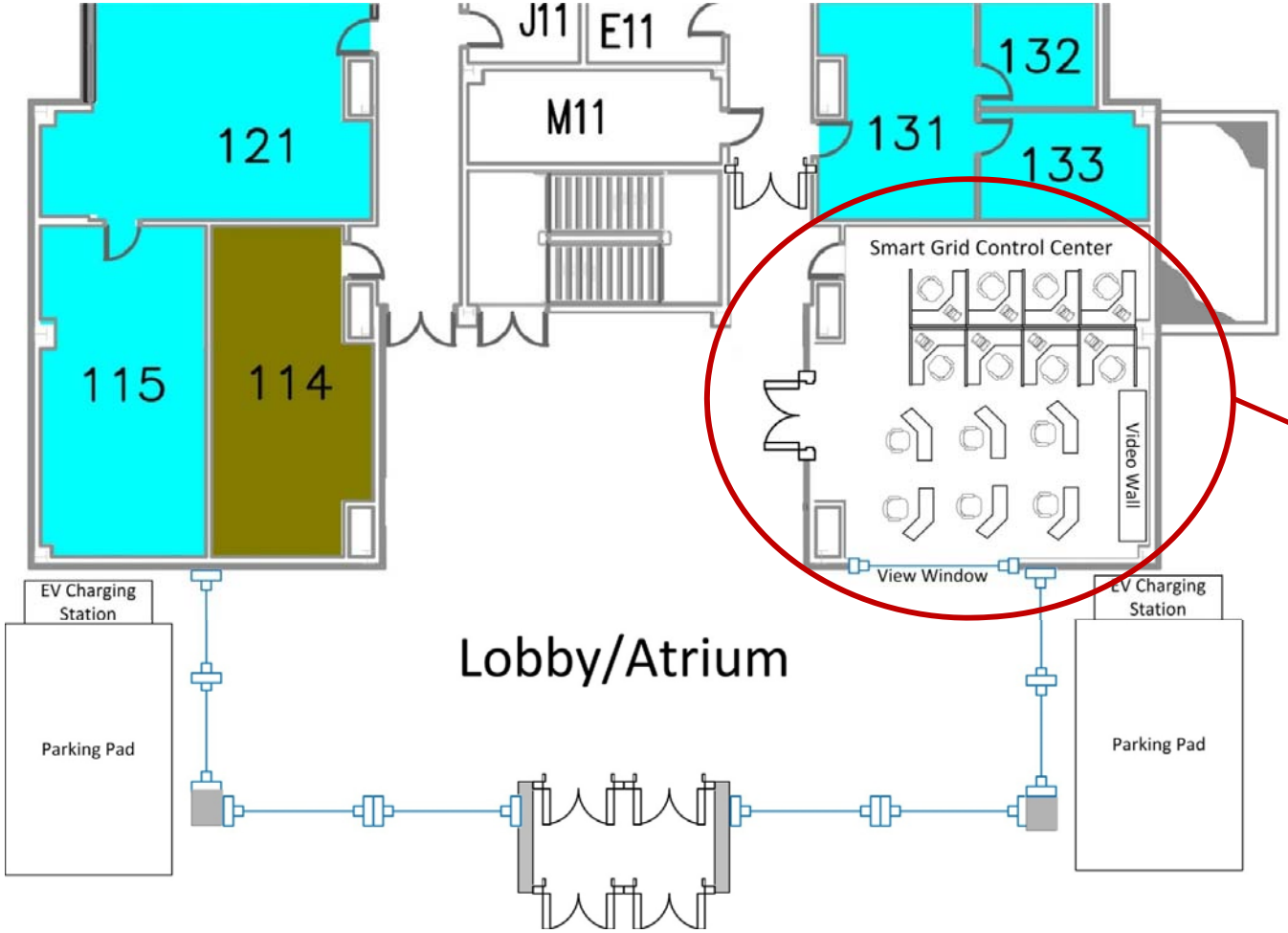
Operations Center

- Infrastructure in service as of July 2014.
- Video Wall and six operator consoles. Teaching/research.
- Cyber Security
- SCADA and Energy Management
- Wide Area Control
- System Protection
- Distributed microgrid and EV operations and monitoring

ECE/EERC Atrium Expansion

- New grand entrance to building, expands lobby
- Fits with EERC bldg theme
- Multi-purpose area for dept functions.
- View window into show-piece smart grid center
- Expanded ECE Academy area, more display cases

Smart Grid Operations Center - EERC 134



Stock photo – energy control center with video wall and operator consoles.

EV Charging Stations. Atrium expansion for departmental functions. Multi-purpose area.